Independent Review Post Fire Resources

Dr Cris Brack
The Fenner School of Environment & Society, Australian National University
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1 Executive Summary

FRAMES – Forest Resource Assessment and Management Evaluation System – has been used to generate strategic yield regulation information for managing the public commercial forests of NSW for multiple decades. There have been several reviews of FRAMES over this period and the system undergoes continuous improvement. Previous reviews have concluded that FRAMES has been found to be efficacious for strategic level forecasting and that FCNSW continues to apply and manage this work appropriately. This review finds no reason to change that conclusion.

The Black Summer Fires – 2019/20 fire season – burnt extensive areas of the commercial forests managed by FCNSW. The RAFIT (Rapid Assessment of Fire Impact on Timber toolkit) developed by FCNSW to assess the range and severity of these fires uses remotely sensed parameters and a widely accepted method to classify areas of disturbance. Five classes, ranging from no impact through to crown fires, where identified from dNBR analyses using flexible dates of data capture, and have been correlated to different levels of vegetation disturbance/impact by experienced observers using photographs collected on site or by UAVs and aircraft. The mapping and classifications generated appear robust and appropriate.

Assumptions related to immediate fire induced mortality, product degrade, interruption of tree growth and regeneration were developed for each of the classes in each of the regions using an “expert approach” and sets of reference photographs. These assumptions were supported by measurements on a site that was burnt in a class 4 – 5 fire about 5 years ago. Statistical support for these assumptions will not be available until repeated field measurements are safe and practical, but in the meantime, I conclude the assumptions made (see Table 1) appear reasonable for strategic planning needs. Sensitivity analysis of key assumptions would help to further build confidence while waiting for statistically valid models to be developed.

Area and yield discounts, including headroom and area average discounts for CIOFA, have remained the same as in strategic analyses conducted over the period 2016-2019. This appears reasonable as there is no *a priori* reason to increase or decrease the total of these discounts in any significant manner.

The constraints and objectives in FRAMES have been changed from those used in analyses over the period 2016-2019. A significant change was the relaxation of constraints for non-declining yield for the initial planning periods (10-20 years). This relaxation is appropriate given the objective of capturing higher quality wood products before they degraded from fire damage. Changes in harvesting priorities were also justifiable to reduce product degradation and improve the scheduling of higher value products where possible. I conclude that these changes are appropriate in the current context.

Comments on regional specific wood flows and strategies will be contained in phase 2 of this review.

2 Introduction / Context

FRAMES is used extensively by FCNSW for strategic yield scheduling and is the basis of the calculations used in relevant RFAs in NSW. The entire system was reviewed in 2016 as part of the RFA 10-year and 15-year reporting and review processes, and again in 2019 (just prior to the Black Summer Fires of the 2019/20 bushfire season) for the north coast region.

The system is flexible and able to rapidly accommodate changes in net area, inventory and growth models. It is also transparent in that any changes to models, input parameters or calibration factors are obvious and easily checked.

The Black Summer Fires - *the worst in living memory* - substantially impacted the forests managed by FCNSW and are expected to significantly alter the sustainable yield flows over the coming decades. However, health and safety issues mean that field inspections of the burnt area are not currently feasible and best "expert" estimates or assumptions will be required to meet timely demands for revised strategic yield schedules.

This is the 1st report of a two phase series and will concentrate on the high-level settings and assumptions used in the strategic yield update conducted by FCNSW in 2020.

2.1 Terms of Reference

Conduct an independent review and provide advice to FCNSW on their post-fire resources and strategic yield regulation estimates. The review will consider updates including:

1. Modelling assumptions to reflect the change in resource condition due to the 2019/20 bushfire season
2. Approaches to quantify bush fire extent and severity
3. Modelling assumptions to reflect the new Coastal Integrated Forestry Operations Approvals (CIFOA) settings
4. Revised constraints and objectives in FRAMES
5. Headroom consideration in FRAMES
6. Reported wood flows

2.2 General Approach

In conducting this Review, I have drawn heavily from my prior experience with the inventory and planning systems of FCNSW, including the related reviews I completed in 2019, 2016 and earlier. There was no expectation or provision for field visits or collection of primary data as part of this review. There was also no expectation or capacity for running model simulations or other analytical exercises.

The 2016 and 2019 reviews had concluded that FRAMES and its underpinning data were efficacious and reliable. However, the 2016 review did recommend some improvements including more use of LiDAR; further analysis on recruitment/ingrowth/mortality; more regular PGP measurement; and integrated calibration with harvesting data. With the exception of LiDAR being used to improve net area mapping, none of the recommended improvements have been able to be incorporated into the 2019 nor the post-Black Summer fires FRAMES analyses.

The documentation provided by FCNSW as part of this review included the "2019-2020 Wildfires NSW Coastal Hardwood Forests Sustainable Yield Review" (June 2020), which forms the basis of this report.

3 Area: severity and extent estimates

Prior to the Black Summer Fires, the Net Harvestable Area estimates were reliable and appropriate. Over several of the RFA sub-regions, LiDAR data had led to significant improvements in improved understanding of the net harvestable area by more accurately mapping water courses, steep areas and other impediments. However simple sample-based average reductions are still applied to deal with some operational constraints and CIFOA restrictions on harvestable area or trees. Significant improvements in species and management history area strata had also been implemented in the 2019 analyses of the north coast.

However the Black Summer Fires were extensive and highly variable in their severity / intensity and new overlays of area affected by fire are essential to understand stocking losses, potential degradation, regeneration and other modelling aspects.

FCNSW developed a remote sensing toolkit - RAFIT, Rapid Assessment of Fire Impact on Timber - which uses Normalised Burn Ration Index (NBR) and the difference in NBR (dNBR) to map fire severity. This is a widely used index and has proven to be reliable in a wide range of wooded ecosystems (Soverel et al, 2011; Picotte and Robertson, 2011; Stambaugh et al 2015; Viana-Soto et al, 2019). FCNSW does appear to be aware of the potential pitfalls of seasonal variation, drought stress, epicormic development and fire-induced leaf fall when using NBR or dNBR. The toolkit, especially with the date "slider" allows some sensitivity of the aspects to be iteratively modelled to improve calibration and overcome these pitfalls.

The range of dates chosen for dNBR and the threshold values for the determining the fire severity classes (1 – 5, no vegetation loss – crown fire) appear appropriate. Validation of the RAFIT mapping using about 700 georeferenced photographs from across the entire spatial range of the fires along with a robust and clear set of class descriptors is excellent practice. However the validation exercise could be further enhanced with a confusion matrix to support FCNSW conclusions that RAFIT is "efficient and effective at modelling a spatially-accurate map for fire severity."

Table 1: Summary RAFIT Classes and impacts

Class	*Descriptor (remotely sensed dNBR)*	*Classification Rules/description in field or photographs*	*Modelling impacts / assumptions*
1	No indication of vegetation loss (<200)	Unaffected forest	No impact
2	Potentially burned, seasonal change or unhealthy. Understorey present (200-350)	Fire, drought or other plant health impacts. Understorey present. Crown mostly green or slight browning.	No impact

3	Moderate burn, below canopy only, understorey heavily impacted (350-500)	Crown mostly intact, with green and brown leaves. Understorey burned.	No growth for 5 years, except in Nth Coast where no impact. Alpine Ash DBH < 30 cm all die immediately Regeneration boost resulting in increased ingrowth in 20 years.
4	Leaves browned but mostly uncrowned. Understorey completely burned (500-680)	Understorey completely burned. Upper-storey leaves browned but mostly not burned	Trees less than 15 centimetres DBHOB die immediately; other trees have no growth for five years; 10 years after the fire, 25%-50% of high quality and all low-quality trees less than 50 cm DBH degrade to pulp quality. Nth Coast, 50% of trees < 30cm DBH and 10% of remaining die immediately. Alpine Ash all die immediately. Regeneration boost resulting in increased ingrowth in 20 years.
5	Crowned/ mostly crowned (>680)	Complete burn including crowns	As above but reduction in quality after 10 years increased to 50%-100% Nth Coast, 100% of trees < 30cm DBH and 50% of remaining die immediately

There was some acknowledged confounding with drought stressed stands receiving a dNBR within class 2 – “low severity” burn where understory is still large intact – which lead to the description to be expanded to include “Potentially burned, seasonal change or unhealthy” stands. It is stated that for this class “… environmental impacts of both drought and low severity fire are incorporated in the base FRAMES growth models” but there is no description of this incorporation. Further details will be required for the subsequent in depth report, especially given drought impacts were identified as an important aspect in the 2016 review.

4 Recovery within classes

Published research on the impact of severe fire on the growth and recovery of merchantable trees is relatively rare and apart from some very general conclusions, seems to be site and species specific. Generally, larger DBH trees, especially once they achieve a threshold minimum have a greater probability of surviving a fire (e.g. Barrette et al, 2012) however larger trees may suffer the greatest relative decrease in merchantable value (e.g. Lowell and Parry, 2007; Lowell et al., 2010) because they move from the highest value products to minimum value pulp or firewood. Recovery of understory species can also be highly variable although eucalypt woodlands and open forests are generally quite resilient.

Field inspections of recovery for sites in the more severe classes were carried out by FCNSW in each region soon after the fire and/or several months later. Safety and logistic issues would not allow these inspections to be systematic or otherwise probabilistic based and so there is no “design-based” assurance of freedom from bias in these inspections. However such an *ad hoc* approach, especially in conjunction with the extensive severity mapping, is presumed to be sufficient for a timely strategic review.

FCNSW acknowledged the deficiencies of the above *ad hoc* recovery study and has commenced a long term study to evaluate how the different components of vegetation are recovering and how they can be measured using various remote sensing approaches. This study will be useful to improve the modelling in future sustained yield calculations. There is no detail on whether this long-term study was established using a design-based or a model-based approach, or whether it includes any relevant PGP sites that were burnt.

The 2016 Goldmine Fire area in Eden provided a “fortuitous” case study that has allowed FCNSW to analyse recovery 4-5 years after similar intensity fires on similar forests. Although limited to one species, one location and a period of relative drought, this case suggests good potential to use externally observed “green height” as a measure of green (valuable) log length. The r^2 indicates a relatively precise correlation and subsequent statistical analysis supports a conclusion that the relationship is free from bias (i.e. not significantly different from a 1:1 line that goes through the origin). The preliminary results agree with the general findings that mortality decreases with increased DBH and, in this case, there may be a threshold for silvertop ash at about 20 cm DBH below which mortality is very likely.

There is a note that field inspections[1] suggested that RAFIT class 2 appeared similar on the ground to “typical low intensity hazard reduction burns” and that therefore there was no expectation that growth or yield would be affected in this class. Earlier it was stated that the effects of such low intensity burns and drought were already incorporated into the base FRAMES models. Presumably this incorporation is assumed to be via the PGP-derived growth models and the implicit assumption that the current period of drought stress is, on average, the same as droughts experienced in the past. It is my understanding that the PGPs have not been recently remeasured or analysed to determine if such an assumption is true. This implicit assumption may be challenged as there is widespread scientific opinion that droughts and drought stress is increasing in recent decades and that even forests “…where tree growth is not mainly constrained by drought…have reported reductions in productivity and widespread increases in tree mortality as a consequence of increasing drought stress” (Peng et al., 2011). My personal observation of growth in the ACT and southern tablelands is that many tree species are growing more slowly than otherwise anticipated by growth models calibrated using pre-2000 measurements. Classes 1 and 2 continue to be

[1] *Ad hoc* or opportunistic? That is, not systematic or probabilistic locations of these sites.

modelled with normal regeneration and mortality assumptions (not updated since questioned for Eden and South Coast in 2016 review).

Similarly, there is a note that field inspections suggested that RAFIT class 3 (with the exception for fire sensitive Alpine Ash) would maintain normal growth and yield after an initial hiatus of about 5 years necessary to rebuild the crown from epicormics growth. As above, this may be slightly optimistic if the PGP-derived growth models do not adequately reflect the increased drought stress impacting the estate. Although there is no fire induced mortality applied in this class, it is assumed that the fire generates a regeneration event that results in an increase in ingrowth (ie. 10 cm DBH trees) in 20 years. Will need to check ingrowth is dominated by shade tolerant species given the lack of opened up canopy and/or that this ingrowth is supported by data derived from PGP plots that have been subject to hazard reduction burns.

RAFIT classes 4 and 5, representing the most severely impacted forests model the fire effects by mortality of smaller sized trees, hiatus of growth for 5 years, and a downgrade of product quality for damaged trees not harvested within 10 years. These model assumptions appear reasonable, although as above may be continuing to use slightly optimistic PGP-derived growth models. Fire induced mortality is applied in these two class, and it is assumed that this results in a regeneration event that results in a significant increase in ingrowth (i.e. 10 cm DBH trees) in 20 years. The assumptions of regeneration in these severely burnt classes are likely to be reasonable given the physiological responses of the major commercial species (i.e. shade intolerant, early successional species).

5 Regional modelling

The strategic inventory plots used for FRAMES in each region where classified into one of the five RAFIT classes and mortality, growth/yield and regeneration estimates modified (Table 1). The headroom safety margin and other "average" discounts to account for operational or CIFOA restrictions were applied as per earlier pre-2019/20 strategic analyses.

The 10% headroom discount was originally introduced to account for fire and other externalities. However the original recommendation is unlikely to have foreseen the "unprecedented" nature of the Black Summer fires and therefore could not be expected to have been sufficient to allow the pre-2019/20 strategic scheduling models to remain appropriate. However, despite the wide extent of these fires it is still possible that external events of the order originally considered when 10% was fixed could impact on the implementation of the strategic plan. It is therefore appropriate to keep this headroom discount at 10%.

The other discount factors to provide for the "average" impact of CIFOA or other operational restrictions is still conservatively estimated at around 15-20%. Improved inventory, especially high resolution LiDAR may reduce the average discount by accurately mapping retention zones and trees but such improvements have yet to be implemented. The impact of fire may also impact on this average percentage reduction - for example, patches of actual/potential habitat trees and clusters may have been burnt and collapsed which means that more trees (from the reduced pool) will have to be reserved.

The assumptions of quality degradation for damaged trees (classes 4 and 5) results in the logical focus of harvesting these areas in the initial scheduling periods as a priority. Relaxing any non-declining yield conditions for the initial scheduling periods results in maintaining a higher yield of quality products in the initial periods. The yields in subsequent periods then drops substantially all the southern regions for a number of periods, which reflects the fire induced mortality and reduced growth for five years. Yields are modelled to finally recover as high quality regrowth become merchantable.

Prioritisation or limitation of areas for harvest in the initial few scheduling periods were also changed in the strategic scheduling exercises of 2019. These changes were designed to improve the rate of recovery, reduce product degradation or in the northern region context maximise optimise the utilisation of trees close to higher quality grades. Such changes in the optimisation process are effective and generally remain appropriate to the circumstances.

The current strategic scheduling exercise separates the next couple of periods from the long term sustainable yield calculation and all regions prioritise capturing products before they degrade from the effects of fire (classes 3 – 5). Thus the current standing inventory and the modelled assumptions about fire induced mortality and product degrade will be most influential. If trees die faster or degrade faster than assumed, the quantity of higher grade material in these initial periods may be adversely affected.

However, the longer-term sustained yields will be more influenced by the assumed regeneration pulses resulting in well stocked and productive regrowth stands eventuating in 20 years. Assumptions about how long net growth will remain in hiatus post-fire and whether they will return to the average growth rates predicated on old PGP measurements will also impact the scheduling over the full planning horizon.

6 Conclusions

FRAMES continues to provide reliable and useful information to support strategic level management and the estimation of long term yield flows. The inventory and growth modelling data underpinning the system has largely remained unchanged since the last major reviews of Eden, Southern and Northern Coast regions. This means that any potential bias discussed in these previous reviews may still be present.

The fire coverage, intensity and severity mapping undertaken by FCNSW appears reliable and robust, and I doubt there are any superior products available. The estimated impact on the standing inventory and subsequent growth of trees by RAFIT classes and species appears to be supported by a large number of in field observation and "practitioner experience", which is appropriate within the health and safety and timing context that bounds this strategic analysis. Some sensitivity analyses to estimate the impact of these assumptions about regeneration/ingrowth and tree growth in the more stressed environment are recommended to improve confidence in the analyses.

Measurements in the near future will be able to test assumptions about mortality, regeneration success and product degradation which is important to build confidence in the estimates for the next 10 – 20 years. Remeasurement and analysis of the PGP system continues to be a priority to build confidence in the longer-term estimates.

7 References

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